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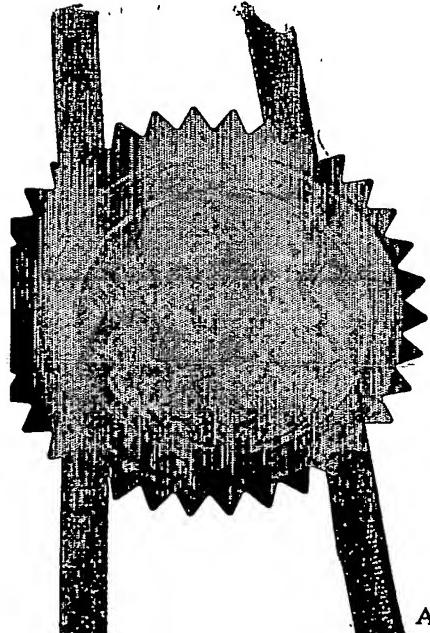
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1. Your reference

TS9280 GBR

2. Patent application number

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3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

SHELL INTERNATIONAL RESEARCH MAATSCHAPPIJ B.V.  
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The Netherlands

Patents ADP number *(if you know it)*

716241001

If the applicant is a corporate body, give the country/state of its incorporation

THE NETHERLANDS

4. Title of the invention

METHOD OF LUBRICATING AN APPARATUS

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

John Michael Overton

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11.

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Signature *Ian E. Davis* Date *18/4/02*  
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METHOD OF LUBRICATING AN APPARATUS

The present invention relates to a process for simultaneously controlling two or more properties of a lubricant or working fluid which lubricant or working fluid is suitable for use in a system which is subject to 5 a range of operating conditions. The invention further relates to apparatus for carrying out said process.

The properties of lubricating fluids vary with changes in the conditions under which they are utilised. For example, the viscosity of a lubricant increases as 10 the temperature of the lubricant decreases. This presents difficulties in designing lubricating systems which provide effective, if not optimum, lubrication over a range of operating temperatures. A lubricant with an optimal viscosity at a high operating temperature may be 15 far too viscous to permit a machine to operate safely in, or even to be started from, cold or low ambient conditions. In response to this problem, lubricating system utilising multiple phases of lubricants have been proposed, for example in International Publication No. 20 WO 96/11244.

However, more than one property of a lubricant or working fluid may vary as conditions under which the lubricant or working fluid is utilised vary. For example, as the temperature of a lubricant or working 25 fluid varies, its viscosity, density, pressure response of viscosity, compressibility and the propensity of the viscosity to change with shear rate, all vary. In many cases, one desirable property may be inconveniently inextricably linked to a large temperature dependence of

another property.

In traction drives, power and torque are transmitted between machine elements having smooth surfaces through fluids or lubricants sometimes called "traction fluids".

5       For example, traction fluids enable one smooth rotating wheel to drive another smooth wheel that is pressed against it, like gears without teeth. The motion is a mixture of rolling and sliding. The traction coefficient is the ratio of the tangential force to the normal force.

10      The normal force is the force that presses the two surfaces together. The higher the traction coefficient, the more effectively the device can transmit power. Therefore it is desirable that the lubricant that is applied to reduce wear by separating the metal surfaces

15      possesses as high a coefficient of traction (also called friction) as possible under all conditions in which the traction drive operates. The improved performance associated with a higher traction coefficient could be exploited, for example, by making the device smaller and lighter.

20      However the traction coefficient of a traction fluid usually varies with temperature, e.g. the traction coefficient under cold start up conditions may be different to that under warm operating conditions. This has the result that devices, such as transmissions for

25      vehicles, cannot be designed to exploit the highest values of traction coefficient.

Furthermore, fluids that possess high traction (i.e. a high traction coefficient) at a particular temperature tend to exhibit a large variation of viscosity with temperature as the temperature changes through that point. To transmit force, the viscosity of the traction fluid must rise to high values as it is subjected to the high pressure in the load-bearing zone between the metal

surfaces. However a rapid increase in viscosity with pressure is usually associated with a rapid change in viscosity (i.e. low-shear ambient pressure dynamic viscosity) with temperature. Conversely fluids which  
5 have a viscosity that changes little with temperature, have a low pressure coefficient of viscosity and, most probably, have a low traction coefficient. Therefore, in selecting a traction fluid, the designer is forced to compromise the value of the traction coefficient so that  
10 the fluid will be of a low enough viscosity at low temperatures to be able to operate. A fluid having a high traction coefficient (e.g. 0.095 or above, measured at a slide-to-roll ratio (SRR) of 2.2 % with a pressure in the contact of 1.125 GPa) at operating temperatures  
15 such as 110 °C, will become unacceptably viscous at lower temperatures, in particular at the cold start-up temperatures that are commonly encountered during winter even in temperate climates. Typically, a lubricant formulated to keep its viscosity low enough for easy cold  
20 starting will possess a traction coefficient at warmed up operating conditions well below the maximum traction coefficient that has been observed in any fluid, of approximately 0.118. Currently the best compromises of traction fluids offer high viscosity at low temperatures  
25 and moderate traction at warmer operating temperatures.

There remains a need for a traction fluid which possesses a high traction coefficient over the entire temperature range within which the traction fluid must operate and which traction fluid has an effective viscosity over the same temperature range. Such a traction fluid would be of particular benefit for infinitely variable transmissions.  
30

A similar conflict between the properties required

at warm operating conditions and those required to permit start up under cold conditions is found for working fluids such as hydraulic fluids for large construction equipment for use, e.g., in severe climates. In such 5 climates start-up temperatures can be as low as -40°C and warm operating temperatures can be up to 95°C. For hydraulic fluids, properties such as viscosity, compressibility and the pressure response of viscosity are important for effective system operation. An ideal 10 hydraulic fluid, for example, might have a low compressibility in combination with pressure- and temperature- independent viscosity. Such a fluid cannot be achieved in practice. Low compressibility is associated with a rapid increase in viscosity with 15 pressure and a strong dependence of viscosity on temperature. To deal with this conflict in properties in hydraulic fluids, operators may resort to "exercising" unloaded hydraulic equipment for an hour before starting productive work in very cold conditions. This is clearly 20 an expensive and unsatisfactory solution to the problem.

There remains a need for an hydraulic fluid which possesses a low compressibility and an effective pressure dependence of viscosity over the entire temperature range that the fluid must operate and which hydraulic fluid has 25 an effective viscosity over the same temperature range.

The present invention solves the above-mentioned problems by providing a process by which two or more properties of a lubricant or working fluid can be maintained at optimal or effective values over a range of 30 system operating conditions.

Thus the present invention provides a process for controlling two or more properties of a lubricant or working fluid which lubricant or working fluid is

suitable for use in a system in which operating conditions change which process comprises:

- (i) providing a base fluid in which the two or more properties are optimal for "warm" operating conditions;
- 5 (ii) providing a diluent which is miscible with said base fluid under all system operating conditions; and
- (iii) reversibly diluting said base fluid with the diluent in response to change in system operating conditions.

10 It has surprisingly been found that, by choosing the base fluid and diluent according to specific criteria, two or more properties of a lubricant or working fluid can be simultaneously controlled by reversible dilution of the base fluid in response to variations in the operating conditions under which the lubricant or working fluid is used.

15 The systems to which the process of the present invention applies include systems which comprise moving components that require lubrication. Such systems may be engines or automobile transmissions that have moving components that require traction fluids. Examples of such moving or operating components are gears, bearings, clutches and traction drive variators. The process of the present invention also applies to hydraulic systems that are actuated by working fluids such as hydraulic fluids under pressure. Examples of moving components in hydraulic systems are actuators. The lubricant of the present invention may have a general lubricating function or it may have other functions such as torque transmission as in traction fluids. The working fluid of

the present invention may be a lubricant that can be used as an hydraulic fluid.

5 In one aspect of the present invention there is provided a process for lubricating a system in which operating conditions change which process comprises:

- (i) controlling two or more properties of a lubricant; and
- (ii) applying the resultant lubricant to the system.

10 In another aspect of the present invention there is provided a process for providing a working fluid for a system in which operating conditions change which process comprises:

- (i) controlling two or more properties of the working fluid; and
- 15 (ii) applying the resultant working fluid to the system.

By applying the resultant lubricant and/or working fluid to the system includes bringing it into contact with a moving or operating component of the system.

20 The properties to be controlled depend on the nature of the task that the lubricant or the working fluid is required to perform in a particular type of machine.

Preferably one of the properties is viscosity as this is a key property for most lubricants and working fluids.

25 By viscosity is meant the low-shear ambient pressure dynamic viscosity. In, e.g. an hydraulic fluid, the compressibility and the pressure coefficient of viscosity may be controlled.

In, e.g. a traction fluid, the traction coefficient may be controlled. In a preferred embodiment, the process of the present invention controls the viscosity in addition to one or more other property (properties) of a lubricant or working fluid for use in a system in which operating conditions are subject to

change. In a more preferred embodiment the process of the present invention controls two properties of the lubricating or working fluid.

In the process of the present invention two or more properties of the lubricant or working fluid are controlled. By controlled is meant that the properties in question are maintained at values which are effective for system operation and are preferably optimal for system operation. The acceptable variation of the value of each property from the optimal "warm" operating conditions value will depend on the property in question. For example, the value of viscosity may increase by 300% from its optimised value and still the lubricant/working fluid will perform effectively. In a traction fluid, preferably the value of traction coefficient is controlled to within +/- 30 % of its optimised value, more preferably to within +/- 15% of its optimised value.

In the process of the present invention the base fluid is specifically selected so that the two or more properties are optimal for "warm" operating conditions. By optimal means that the two or more properties of a particular composition of base fluid are such that the system performs better with respect to at least one, and preferably both, of these properties at "warm" operating temperatures than at cold start up or ambient operating temperatures. For example, the base fluid may be a traction fluid which has a high coefficient of traction and low viscosity at "warm" operating temperatures but has a low coefficient of traction and high viscosity under cold start up conditions.

"Warm" operating conditions are conditions under which the system is at a temperature greater than that under cold start-up or ambient conditions. Cold start up

conditions can give rise to temperatures in the range -  
5      40°C to 25°C depending on the climate. "Warm" operating  
      conditions include operating conditions at which the  
      system spends most of its working time, e.g. the working  
      temperature of a machine. "Warm" operating conditions  
      can include a range of temperatures up to the highest  
      operating temperature of the system and may include  
      different operating conditions of different components in  
      the system. Typically for automotive traction drives  
10     this range is from 90°C to 150°C. In large items of  
      hydraulic equipment under warm operating conditions the  
      temperature of the working fluid can be in the range of  
      50 to 95 °C.

15     In a preferred embodiment, the base fluid has a high  
      traction coefficient and a low viscosity at "warm"  
      operating temperatures. Preferably the base fluid has  
      traction coefficient measured at 2.2% SRR under a load of  
      1.125 GPa, of greater than 0.08 at temperatures between  
20     90 and 150 °C and a viscosity of less than 100 mPas over  
      the same temperature range. Suitable high traction  
      fluids may contain a high proportion of saturated rings  
      linked by short chains or fused in pairs or larger  
      clusters. Base fluids may be hydrocarbons or esters or  
      contain ether or carbonate groups. Certain commercially  
25     available products such as Techtrac M73 (Trade name)  
      contain mixtures of molecules having two or three  
      cyclohexyl rings connected by methyl-branched alkyl  
      chains. Molecules of this type can be regarded as  
      hydrogenated dimers and trimers of β-methyl styrene.  
30     Suitable base fluids can be prepared from these products  
      by varying the proportion of trimers relative to that of  
      dimers in the product. Varying the ratio of dimers to

trimers varies the temperature at which the fluid has a maximum traction coefficient. Thus in one embodiment of the present invention, the proportion of dimers to trimers is selected so as to provide a base fluid with a maximum coefficient of traction at a particular 5 temperature, i.e., the base fluid is custom-designed for a particular temperature range of "warm" operating conditions. Preferably the base fluid comprises a mixture of dimers and trimers containing approximately 10 10% by weight dimers and 90% by weight trimers. By approximately in this context is meant +/- 3%.

The present invention provides a lubricant in which the traction and the viscosity of the lubricant can be maintained within narrow ranges over the entire 15 temperature range that the traction drive operates from the coldest start to the peak operating temperature. Such constancy of properties cannot be achieved in a single fluid of unchanging composition. Hitherto it has been believed that the property of high traction 20 exhibited by certain fluids under some conditions is a narrow and specific consequence of their composition and that the property of high traction would be lost on admixture of another fluid into the traction fluid. However, it has now been found that by choosing the base 25 fluid and diluent according to specific criteria, the property of high traction possessed by the base fluid at one temperature can be maintained or nearly maintained at other temperatures by reversibly diluting the base fluid with the second fluid in specific ratios that depend upon 30 the temperature. In this way two properties that are important in traction fluids, namely the viscosity and the traction coefficient, may be both maintained close to optimum values over a very wide temperature range (150°C)

using this technique of reversible dilution.

The diluent and the base fluid are selected so that they are miscible under all operating conditions. By miscible is meant that the diluent and base fluid dissolve when brought together and form one phase. "All operating conditions" includes cold start up or ambient conditions and "warm" operating conditions. The present invention therefore provides a single phase lubricating system suitable for use in a system in which operating conditions change. This provides significant advantages over the multiphase lubricating processes of the prior art.

Suitably the base fluid has a higher viscosity and a lower volatility than the diluent. In the case of the traction drive, the base fluid will typically have a viscosity greater than 5 mPas at 100°C and the diluent will typically have a viscosity below 1 mPas at 100 °C and below 10 mPas at 0°C.

Suitable diluents will possess a low viscosity especially at temperatures below 0°C. The lower the viscosity of the diluent, the less is required to decrease the viscosity of the base fluid mixture. Suitably, the diluent has a melting range below -40°C and a melting point below -50°C. The boiling range of the diluent should be low enough to enable it to be removed by evaporation from the mixture either at ambient or at reduced pressure. Examples of suitable diluents are decalin which is a mixture of cis- and trans- isomers of decahydronaphthalene and CYPAR-9 (trade name), a commercially available solvent manufactured by Shell Chemicals in the USA, which predominantly contains methyl-substituted cyclohexanes with 9 carbon atoms. The

diluent may also be a fuel such as gasoline or diesel.

Liquid hydrocarbon fuel oils of the gasoline boiling range are typically mixtures of hydrocarbons boiling in the temperature range from about 25°C to about 232°C, comprising mixtures of saturated hydrocarbons, olefinic hydrocarbons and aromatic hydrocarbons.

The base fuel oil is derived from straight run gasoline, polymer gasoline, natural gasoline, dimer and trimerized olefins, synthetically produced aromatic hydrocarbon mixtures, from thermally or catalytically reformed hydrocarbons, or from catalytically cracked or thermally cracked petroleum stocks, and mixtures of these.

The hydrocarbon composition and octane level of the base fuel are not critical. The octane level,  $(R+M)/2$ , will generally be above about 85 (where R is Research Octane Number and M is Motor Octane Number).

Liquid hydrocarbon fuel oils which are middle distillate fuel oils typically have a boiling range in the range 100°C to 500°C, e.g. 150°C to 400°C.

Petroleum-derived fuel oils may comprise atmospheric distillate or vacuum distillate, or cracked gas oil or a blend in any proportion of straight run and thermally and/or catalytically cracked distillates. Such fuel oils include kerosine, jet fuels, diesel fuels, heating oils and heavy fuel oils.

Diesel fuels typically have initial distillation temperature about 160°C and final distillation temperature of 290-360°C, depending on fuel grade and use.

In a preferred embodiment, the diluent may comprise a mixture of hydrocarbons and/or organic esters having a boiling range within the range of from 50 to 200°C.

In the process of the present invention the base fluid is reversibly diluted with the diluent in response to a change in the system operating conditions. The process further comprises a step in which a change in 5 operating condition is detected directly or indirectly, e.g. by monitoring one or more properties of the lubricant. The properties of the lubricant that are monitored may be temperature, viscosity, composition, traction, density and refractive index amongst others.

10 Removal or separation of the diluent from the base fluid can be effected by means such as evaporation or distillation. In one embodiment of the present invention, energy generated by the system being lubricated is utilised to provide at least part, and preferably all, of the energy required in the separation 15 of the diluent from the base fluid. This has clear benefits in the efficiency of the process of the present invention.

20 The energy generated by the system may be, e.g., heat energy, mechanical energy or electrical energy. The energy may be generated directly by the operating components being lubricated or to which the working fluid has been applied, e.g., heat energy. The energy may be generated indirectly by the system, e.g., heat energy produced by an engine which drives wheels through a 25 transmission or electricity produced by an electricity-generating windmill which comprises a traction drive.

The present invention further provides apparatus suitable for carrying out the process of the present 30 invention which apparatus comprises means for reversibly diluting the base fluid with the diluent and means by which energy generated by the system is utilised to provide at least part of the energy required in the

separation of the diluent from the base fluid. The means for reversibly diluting the base fluid with the diluent include means for adding the diluent to the base fluid and means for removing diluent from the base fluid.

5 The apparatus of the present invention may further comprise:

- (i) reservoir means comprising a diluent;
- (ii) a mixing zone comprising a base fluid;
- (iii) dispensing means for supplying the diluent from the 10 reservoir means to the mixing zone;
- (iv) separating means for removing diluent from the mixing zone; and
- (v) means enabling the contents of the mixing zone to contact an operating component of the system.

15 The mixing zone may be, e.g. the sump or main fluid reservoir for a transmission or the main fluid reservoir in a hydraulic system. The means enabling the contents of the mixing zone to contact an operating component of the system may comprise a series of pumps and an oil circuit.

20 The apparatus may also comprise means for monitoring a change in system operating conditions such as a programmable controller which may form part of a main engine management system. The programmable controller 25 may be used to assess the current composition and properties of the mixture and to instigate the withdrawal or addition of diluent as required by the state or operating condition of the machine.

The apparatus of the present invention comprises 30 means for separating the base fluid from the diluent. Separation may be effected by evaporation or distillation of the relatively volatile diluent from the mixture of

diluent and base fluid, optionally under reduced pressure. The separating means typically consists of a device to perform flash distillation, vacuum distillation or distillation of the mixture of base fluid and diluent.

5 Separation can be controlled to remove the diluent from the mixture at the desired rate. In one embodiment, the lubricant or working fluid is pumped to the separator by an oil pump, preferably the system's main oil pump, with a proportion of the lubricant/working fluid flow being

10 passed through the separator. This proportion is variable from 0 to 100%.

In the separating means the incoming mixture is heated to a temperature high enough to form an appreciable vapour pressure of the relatively volatile diluent. The vapour and the depleted residual base lubricant are separated, this may be achieved using a pump. The vapour can then be condensed and stored for re-use and the residual base lubricant can be re-injected into the lubricant circuit at some point, for example, at the sump.

Energy is required to heat the mixture to the separation temperature and to evaporate the diluent. The apparatus of the present invention further comprises means by which energy generated by the system being lubricated or to which the working fluid is applied is utilised in the separation of the diluent from the base fluid. In one embodiment of the apparatus of the present invention, the separator draws some of the heat required for the separating step from the surplus heat rejected by the engine that drives the machine. Engines reject excess heat into the coolant (water/antifreeze), into exhaust gases, and into the engine lubricant. Sources of heat for the separator are the hot water coolant from the

engine, and the exhaust gases. In general the distillation step will operate by removing a small proportion of the liquid flowing through it. It follows that much of the heat put into the lubricant mixture to raise it to the distillation temperature, can be recovered and used to heat the incoming flow of fresh mixture into the separator.

The separator may consist of one or several heat exchangers through which the incoming mixture passes in sequence before reaching the distillation chamber. These heat exchangers are used to progressively raise the temperature of the incoming mixture, and can be used to lower the temperature of the depleted mixture after it has passed through the distillation or evaporation chamber. A typical sequence might pass the incoming base fluid/diluent mixture through one or more of the following stages, each being identified in the list by the source of the heat that is used to raise the temperature of the incoming mixture:

- (a) Engine hot water stage, in which the incoming mixture is heated, e.g. from the current sump temperature to approximately 85°C, by thermal contact with hot water from the engine cooling system. Such hot water is generally available after approximately a minute of engine operation. This heat exchanger can operate passively until, e.g., the incoming mixture reaches 85°C, at which point the flow of water may be switched off.
- (b) Hot lubricant stage, in which the incoming mixture is heated by thermal contact with a stream of lubricant or working fluid that has passed through the evaporation chamber.

- (c) Diluent vapour condensation stage, in which hot vapour from the distillation chamber is condensed, realising the heat of vaporisation to the incoming mixture.
- 5 (d) Engine-exhaust heating stage, in which heat is obtained, most probably by an indirect method, from the hot exhaust gases. This stage might be combined with stage (c), using vapour produced by boiling the diluent in a tube around the exhaust pipe to transfer heat.
- 10 (e) Electrical heating stage, most probably forming part of the evaporating chamber, in which the input steam is heated finally to the temperature at which the separation by evaporation proceed at the desired rate.

In one embodiment of the present invention, one of more of the heating stages operate passively, with the proviso that certain flows may be stopped by closing valves at some temperatures. Furthermore, the optional stage in (d) in which heat is transferred from the exhaust by condensing vapour, can be designed so as to stop automatically when the evaporation of the diluent from the mixture is complete.

The use of reduced pressure, that is a pump to move the vapour that evaporates from the mixture, may form part of the separator scheme. The vapour pump may be mechanical, such as an axial or a turbine compressor, or a vane pump, or a centrifugal pump; or alternatively it may take the form of a vapour jet ejector pump, whose application is described in more detail below. The purpose of the pump is to enable the separation of vapour and mixture to occur at a lower temperature. It is not necessary that the pressure be reduced to a point at which the mixture would boil. The purpose of the pump would be to remove the vapour that is in equilibrium with

the mixture, so as to permit the evaporation of more vapour.

If a vapour-jet ejector is used as the pump, the motive gas for the ejector could be the vapour of the compressed diluent itself. The compressed liquid would need to be heated to a temperature high enough to ensure that the vapour saturation pressure provides the necessary motive flow through the ejector. The heat for this could be obtained from the surplus heat of the engine. The flow of motive gas or vapour through the ejector would be combined with the 'suction flow' of vapour (of the same composition) coming out of the mixture. This jet of vapour would be condensed to liquid in a heat-exchanger, transferring the heat of the condensing vapour to one or both of two other liquid streams: the flow of diluent towards the high-pressure, high-temperature side of the vapour jet ejector, and the flow of oil/diluent mixture towards the separator.

The motive gas for the ejector could alternatively be steam which could be generated by using surplus heat from the engine or energy from another source. The steam combines with the suction flow of vapour in the diffusion zone of the ejector and both vapours are condensed so as to impart their heat usefully to other streams as described above. The condensed water and diluent, being immiscible in the liquid phase can then be separated for re-use in a reservoir. The water does not act as a lubricant and does not contact the lubricated surfaces.

In yet another variant, vapour may be drawn from the environment of the lubricated machine part. For example, in the traction drive, the fluid is used to lubricate machine parts that are moving rapidly and imparting heat to the lubricant. It is anticipated that the movements

of the machine parts will create films and droplets of lubricant so that the total surface area of the lubricant will be large enough to facilitate rapid evaporation of the diluent vapour. This vapour can be pumped away continuously, separating droplets of the base fluid as necessary. This approach is beneficial in avoiding the development of flammable concentrations of vapour in the spaces surrounding lubricated machine parts.

The process of the present invention is illustrated by the following example.

Example 1

In this example, the variation with temperature of traction coefficient and viscosity of a lubricant according to the present invention was investigated.

Viscosity measurements were made with a Rheolyst cone-on-plate rheometer. Traction coefficients were measured using a "Mini-Traction Machine" manufactured by PCS Instruments Ltd of London. In this device, a polished steel ball (3/4 inch diameter) is caused to rotate against a polished steel ring which is also rotated. The speeds of the ball and the ring are controlled separately so that the ratio of the sliding motion to rolling motion can be adjusted by the machine. The pressure in the contact is adjusted by the load applied to the arm that bears the rotating ball. The ball and ring are immersed in the lubricant whose temperature is controlled. Measurements were made at different slide-to-roll ratios (SRR) and under different applied loads. Most of the results quoted have been obtained at 2.2 % SRR under loads that generated pressures close to 1.125 GPa in the lubricated contact. The remaining results were obtained at other values of the slide to roll ratio. These were corrected to provide

an estimated value of the traction coefficient at 2.2 % SRR.

The base fluid used was a distillation cut of commercially available Techtrac M73; a mixture of 5 hydrogenated dimers and trimers of  $\beta$ -methyl styrene such that the trimers are about 90 % by weight of the mixture and the dimers are about 10 % by weight of the mixture. By about in this context is meant +/- 3%. The diluent used was CYPAR-9, a commercially available solvent which 10 predominantly contains methyl-substituted and ethyl-substituted cyclohexanes with 9 carbon atoms. CYPAR-9 is manufactured by Shell Chemical in the USA.

The viscosity and the traction coefficient of the base fluid were measured as a function of temperature. 15 The results are shown in Table 1.

Table 1

Temperature/°C	Traction Coefficient	Viscosity/mPas
150	0.097 <sup>1</sup>	5.0*
140	0.102 <sup>m</sup>	6.5
130	0.106 <sup>2</sup>	8.9*
120	0.109 <sup>2</sup>	12.5
110	0.110 <sup>2</sup>	18.6*
100	0.111 <sup>m</sup>	29.3
90	0.109 <sup>2</sup>	49.6*
80	0.104 <sup>2</sup>	92.5
70	0.094 <sup>m</sup>	195*
60	.	484
50	.	1500*
40	.	6272

The viscosity at these temperatures was obtained by interpolation, using a Vogel expression fitted to the measurements made at other temperatures. The Vogel expression fitted the data closely above 40°C.

5     <sup>m</sup> Direct measurement

<sup>1</sup> Estimated

<sup>2</sup> Measured at 5 % SRR and corrected to 2.2%. To make the correction, the values were reduced slightly from those measured. The largest correction was 0.006.

10     As shown in Table 1, this lubricant possesses a high and nearly constant traction coefficient over much of the range of temperature of importance in the warm operating condition (70 to 150°C). Furthermore the traction coefficient declines steeply as the temperature falls below 60°C. The viscosity changes quite slowly in the temperature range 100 to 150°C, but at lower temperatures begins to increase rapidly and exceeds 6 Pas at 40°C and 43 Pas at 30°C. On inspection, this fluid can be seen to be unacceptably viscous at room temperature.

15     The base fluid was then mixed with varying amounts of the diluent. The traction coefficient and the viscosity at varying temperatures of the resultant mixtures were then measured. By tracing the traction coefficient as a function of composition and temperature 20 it was established what mix of base fluid and diluent would be optimum at each temperature. The results are 25 shown in Table 2.

Table 2

Temperature /°C	Traction Coefficient	Viscosity/mPas	Wt% diluent in mixture
100	0.111	18.6	1
90	0.109		1.9
80	0.108 <sup>M</sup>	55 <sup>E</sup>	4.3
65	0.106 <sup>M</sup>	60 <sup>E</sup>	9.6
55	0.102	54	14.2
45	0.097	36	19.4
30	0.095 <sup>M</sup>	40 <sup>E</sup>	27.5
0	0.094	51	36.6

<sup>E</sup> Estimated since no measurement available at precisely these conditions.

5       <sup>M</sup> These are the minimum traction coefficients expected at these conditions. No measurements were available at precisely the correct conditions. These numbers are measurements made at these temperatures but on concentrations that are not quite optimum.

10       The results in Table 2 shows that the viscosity and traction coefficient of a base fluid can be controlled by progressively diluting a base fluid with a liquid consisting predominantly of methyl-substituted cyclohexanes. If no further dilution were made and the 15 composition shown at 0°C were retained to a temperature of -40°C, the viscosity would increase to approximately 0.5 Pas. Such a viscosity is far lower than that achieved by other traction fluids. In particular the results show that the maximum traction coefficient can be maintained at lower temperatures while simultaneously keeping the viscosity under control. From these results 20 it can also be concluded that the above traction fluid

mixture is suitable for use in traction devices where the operating temperature is expected to lie in the range of 70 to 150°C, where the lower temperature is the temperature of the reservoir of the base fluid and  
5 diluent mixture and the upper temperature is that experienced in the track where one element of the traction drive rolls over another so as to transmit the torque.

C L A I M S

1. A process for controlling two or more properties of a lubricant or working fluid for use in a system in which operating conditions change which process comprises:

(i) providing a base fluid in which the two or more properties are optimal for "warm" operating conditions;

5 (ii) providing a diluent which is miscible with said base fluid under all system operating conditions; and

(iii) reversibly diluting said base fluid with the diluent in response to change in system operating conditions.

10 2. A process as claimed in claim 1 wherein the two properties are viscosity and one selected from traction coefficient, compressibility or pressure response of viscosity.

15 3. A process as claimed in claim 1 or claim 2 wherein the base fluid has a traction coefficient which is above 0.08 (at 2.2 % SRR and 1.125 GPa) and a viscosity of less than 100 mPas in the temperature range 90 to 150 °C.

20 4. A process according to any one of the preceding claims wherein the base fluid comprises a mixture of dimers and trimers of hydrogenated β-methyl styrene.

25 5. A process according to claim 4 wherein the proportion of dimers to trimers is selected so as to provide a base fluid with a maximum traction coefficient at a particular temperature.

6. A process according to claim 4 or claim 5 wherein base fluid comprises dimers to trimers in a weight ratio of 10:90.

7. A process according to any one of the preceding claims wherein the diluent is chosen from a fluid comprising a mixture of cis and trans isomers of decahydonaphthalene and a fluid comprising methyl-substituted and ethyl-substituted cyclohexanes with 9 carbon atoms on average.
- 5
8. A process according to any one of the preceding claims wherein the diluent comprises a mixture of hydrocarbons and/or organic esters having a boiling range within the range of from 50 to 200°C.
- 10
9. A process for lubricating a system in which operating conditions change which process comprises
- (i) controlling two or more properties of a lubricant in accordance with the process of any one of the
- 15 preceding claims; and
- (ii) applying the resultant lubricant to the system.
10. A process for providing a working fluid to a system in which operating conditions change which process comprises
- 20 (i) controlling two or more properties of the working fluid in accordance with the process of any one of claims 1 to 8; and
- (ii) supplying the resultant working fluid to the system.
11. A process according to any one of the preceding
- 25 claims wherein the step of reversible dilution involves a step of removing diluent from a mixture of base fluid and diluent by evaporation or distillation and energy generated by the system is used to provide at least part of the energy required for this step.
- 30 12. A process according to claim 11 wherein the energy generated by the system is supplied from one or more of:
- (i) hot water from the system cooling system;

(ii) lubricant or working fluid that has already passed through an evaporation or distillation stage;

(iii) heat of vaporisation from hot vapour in a distillation or evaporation chamber;

5 (iv) exhaust gases; and

(v) an electrical heating stage.

13. An apparatus for carrying out the process of any one of the preceding claims which comprises:

(i) reservoir means comprising a diluent;

10 (ii) a mixing zone comprising a base fluid;

(iii) dispensing means for supplying the diluent from the reservoir means to the mixing zone;

(iv) separating means for removing diluent from the mixing zone; and

15 (v) means by which energy generated during operation of the system is utilised by the separating means to separate the diluent from the mixing zone.

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A B S T R A C T

METHOD OF LUBRICATING AN APPARATUS

The present invention relates to a process for controlling two or more properties of a lubricant or working fluid for use in a system in which operating conditions change which process comprises: (i) providing  
5 a base fluid in which the two or more properties are optimal for "warm" operating conditions; (ii) providing a diluent which is miscible with said base fluid under all system operating conditions; and (iii) reversibly diluting said base fluid with the diluent in response to  
10 change in system operating conditions. An apparatus for carrying out said process is also disclosed.